

MEMORANDUM FOR:

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NPIC/P&DS/D/6-1649  
26 October 1966

MEMORANDUM FOR THE RECORD

SUBJECT: Seventh National Symposium on Information Display

The Society for Information Display held its Seventh National Symposium in Boston on 18-20 September 1966. The Society concerns itself with "all methods and media used to present dynamic information to people." It was my privilege to attend the first two days of the meeting.

The technical sessions encompassed a wide range of science and engineering fields including information theory, information processing, human factors research, system design, optics, electro-optics, and storage media. A considerable amount of the presentation included human factors research on viewing systems, keyboarding operations, etc. Included with this memorandum is a copy of the abstracts of the papers felt to be of interest to our staff. I have a copy of the technical session proceedings that will be available to anyone desiring further information.

The exhibits were rather disappointing in that there were only about a dozen manufacturers represented. Inasmuch as the attendance of the Symposium must have approached a thousand it is felt that more companies would have participated. While reviewing the exhibits I talked with some representatives of Litton Industries Electron Tube Division.

They manufacture high resolution, flat tubes. I asked [redacted] if a CRT with a small spot size could be used at about a 500 line display mode to present visual data to an observer and then switched to a 2000 (or greater) line mode for hard copy making. Even though the high resolution mode would probably cause flicker, the camera used in obtaining the copy would integrate the flicker on the film. [redacted] felt that such a system could readily be assembled although he warned that any high resolution system would be expensive. This two mode system may be a compromise method of transmitting detailed pictorial information.

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As part of the Symposium, I attended a field trip to the Air Force Cambridge Research Laboratories where an exhibit of an on-line computer-controlled color oscilloscope was used for graphic data presentation. Straight lines, circles and other pre-selected symbols could be composed in color on a CRT. Although the system was adequate for producing simple line drawings or wiring or piping diagrams, it did not present the clarity and high quality produced by this building's graphics personnel.

Also demonstrated were some real-time man-computer communication capabilities in the form of visual games: "Space War" and "Billiards". While these programs are used for dramatizing the uses of these displays, they are in themselves of little value. Nevertheless, they are extremely interesting and the "Space War" game will be described to illustrate the types of real-time information that can be displayed on these systems.

Two rocket ships are displayed on a CRT. Each player has control of the speed, direction, and attitude of his space vehicle. He also is able to fire bullets in an attempt to destroy his opponent's ship. His number of bullets and fuel are limited so that they must be used conservatively. In order to complicate the game a sun can be placed in the center of the screen. The sun's gravitational force tends to draw the rocket ships toward it so that the participant must maneuver to avoid crashing into the sun's surface.

I encourage all P&DS personnel to read the abstracts attached to this memorandum. Please see me if you desire further information from the published proceedings.

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HUMAN PERFORMANCE STANDARDS IN DISPLAY SPECIFICATIONS



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Abstract

A new form of specification for display equipment has been written for several computer-based systems. This form departs from the conventional form in many ways, the most unusual of which is a section on legibility testing. The testing involves humans who perform recognition and reading tasks, and the errors and times of reaction are given as acceptance criteria and standards for the display. The usual display parameters are given as design guides or as suggested ranges of values.

The new form has several advantages over the conventional form. It is clearer, more precise, less redundant, and more directly relevant to actual requirements of any visual display, namely, its visual quality. The new form has some limitations, but these are subject to improvement by typical laboratory methods.

Reactions to this new form have been favorable after an initial period of confusion and mistrust. Since this form of specification emphasizes what is wanted in a visual display, it shows promise of increased usefulness in the future, and can provide a new basis for display standards.

The information contained in this document has been released for public dissemination by the Directorate for Security Review, Office of the Secretary of Defense.

EXTENDING IMAGE REPRODUCTION SYSTEM  
ANALYSIS TO INCLUDE THE OBSERVER

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ABSTRACT

Image reproduction systems such as photographic projection and television displays produce a visual display which is an analog reproduction of a source pattern. The technique of employing a modulation transfer function (MTF) to characterize image reproduction systems of all kinds has been found very useful for predictive analysis. While such analytical methods are effective for characterizing physical image systems, they have not provided quantitative evaluation of the display from the observer's viewpoint.

Recently, efforts have been made to define a modulation transfer function that characterizes a standard human observer and could be combined with the MTF of the physical image system to evaluate the total display-observer system. This approach can be shown to be invalid, since the human visual system, unlike the physical system, does not respond at all at contrast levels below the contrast threshold and, above this threshold, responds as a nonlinear function of modulation (contrast).

This paper proposes a graphical method for extending image reproduction system analysis to include the observer. A procedure is outlined for plotting the contrast threshold function of a standard observer on the same coordinates as the system modulation transfer function; obtaining difference values which represent the objective physical modulation (or contrast) transfer above threshold; and finally, converting the physical modulation levels above threshold to the Munsell psychophysical response scale.

EVALUATION OF SOME DISPLAY PARAMETERS  
WITH HUMAN PERFORMANCE MEASURES

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ABSTRACT

The physical parameters which affect display "quality," such as screen luminance and contrast, are well known and readily measured. However, display system designers need to know how the user of the display, the human observer, will perform as a function of many display parameters. Traditional human factors literature is helpful, but such sources usually treat the human visual process at threshold levels and typically consider only one of the many physical parameters at a time. Therefore, human performance measures are generally necessary to evaluate the effects of specific parameters in the suprathreshold situation of complex real display systems. Subjective judgments, such as preferences for various physical parameters, can also be obtained, but such criteria usually show high variability and are often misleading.

In a study conducted with a rear projection teaching machine, human performance measures were used to evaluate certain display parameters. The physical parameters of screen luminance, ambient illumination and image polarity (positive or negative) were investigated. The human performance measures were the amount of time taken and the number of errors made on a programmed course of instruction. Preference information was also obtained as a function of the physical parameters by allowing the observer freedom in choosing his viewing conditions. The preference information here shows a positive correlation with the performance measures.

In another study, television displays were compared to film displays to determine points of equal "quality." The physical parameters were character size, television bandwidth and original film image size. The human performance measure was legibility, i. e., the percent of correctly identified letters. Preference information was also obtained which demonstrated how discrepancies can occur between subjective judgments and objective performance measures.

## NUMERICAL DISPLAY EVALUATION

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Abstract

An exploratory study of numerical display evaluation techniques is reported. A general formula applicable to display systems for any complex larger system with a well defined mission is presented. This formula is simply a tool for evaluating the effect of mistransfer of information from the display system to the operator on the probable outcome of the mission. Besides a general formula, several other general conclusions are drawn. First, an adequate numerical display evaluation technique must be highly complex. The implication is that in many cases judgments must be made by only partially adequate techniques. Second, numerical display evaluation analysis allows game theory to be applied on both display design and system design to achieve optimum matching between the display and the system in which it is incorporated. Third, numerical display evaluation is unsuited to certain broad classes of displays.



## A NEW DEVICE FOR VERSATILE DISPLAY SYSTEMS: THE ELECTROSTATIC STORAGE DISPLAY TUBE



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### ABSTRACT

A novel approach to the storage and display of information combines the intrinsic charge-storage property of a dielectric membrane and the high-speed, high-resolution capability of a newly developed electron gun with an independent optical system to provide bright, high-contrast, large-screen display.

This technology has now been incorporated in a new display tube which does not require the use of vacuum pumping equipment. The tube essentially separates the writing/recording function from the actual display function and thus provides several significant advantages over conventional storage display tubes. The write gun can be designed for high resolution at very high writing speeds. It does not draw a high current since there is no phosphor to be excited.

The optical display system can be independently designed for a number of specific applications from high-density recording on film to bright, flicker-free, theater-size displays. Other advantages include resolutions of the order of 2000 TV lines per useful field of view, frame writing times varying from about an hour down to a few milliseconds, storage times of over one month (requiring no electric power), and update or cycle times of less than 100 milliseconds.

### 1. GENERAL DESCRIPTION

The Electrostatic Storage Display Tube (ESDT), originally conceived by C. K. Clauer and J. D. Kuehler,<sup>(1)</sup> is a two-chamber cathode ray tube. The two chambers are separated by a thin dielectric membrane which serves as

the recording and storage medium. One of the chambers contains a high-resolution electron gun and, usually, a secondary flood gun. The other chamber contains an electrographic developer. Schematically, this is shown in Figure 1. The electrographic developer is a mixture of

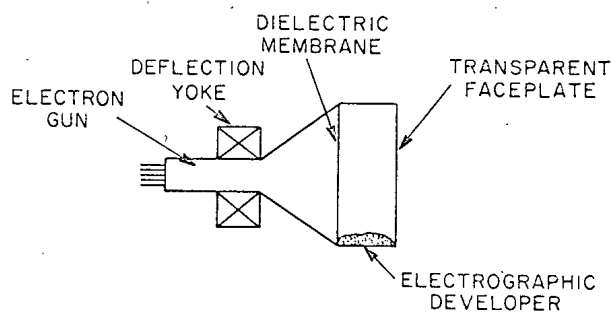


Fig. 1. Basis of electrostatic storage display tube

carrier beads and a pigment or toner, which, when triboelectrically excited, leaves a net positive charge on the toner particles.

Basic technology, as used in conjunction with demountable type tubes, has been described in a previous

(1) C. K. Clauer and J. D. Kuehler, "Electrostatic Writing and Printing Device," U.S. Patent #3,109,062 (October 29, 1963).

CAPACITY AND OPTIMUM CONFIGURATION OF DISPLAYS  
FOR GROUP VIEWING



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Abstract

Deterioration of legibility with increasing viewing distance and obliquity limits the amount of information a display screen can convey to an immobile audience. The resulting display capacity and the degree of its utilization determine the efficiency of the display, where efficiency relates audience area to screen size for the most favorable screen/audience configuration.

The underlying geometric relationships, derived from legibility experiments, are presented in quantitative form and illustrated by examples. Their application enables a designer to determine optimum display configurations on the basis of geometry rather than intuition.

NON-LINEAR OPTICAL FILTERS  
FOR HIGH CONTRAST DISPLAYS

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## ABSTRACT

A new class of hybrid optical filters has been developed which exhibits markedly different transmission properties in opposite paths through the filter structure. In one direction, optical energy may be efficiently transmitted with only moderate effective attenuation; in the opposite direction, the filter will almost totally absorb energy, with negligible specular or diffuse reflection. This unusual transfer function is obtained by a combination of both fluorescent and passive optical media, and in part exploits the irreversible Stokes' Law emission property common to fluorescent materials.

The presence of complementary "easy" and "hard" transmission characteristics is akin to diode-like action for energy transfer at optical wavelengths, and suggests application for efficient contrast enhancement for a number of classes of displays in the general aerospace environment. ~~Present analysis indicates that this filter class will provide a high immunity to washout under direct ambient illumination, at acceptable brightness levels which will not fatigue the observer, and without restriction of the angle of view.~~ Application of the technique to a CRT display is presented.

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## HIGH RESOLUTION MULTI-COLOR STORAGE TUBE

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### ABSTRACT

Color display storage tube having resolution and environmental ruggedness equal to monochromatic display storage tubes has been demonstrated.

The structures utilized in this new tube design are identical to those in standard direct view storage tubes except for a special phosphor. There is no phosphor dot structure to align with the target assembly and only one writing gun is needed.

The stored color is determined by the storage surface potential or halftone level to which that portion of the display has been written. The color in this color storage tube is thus seen to be a function of the grid drive, the sweep speed or, since the storage tube is an integrating device, the number of pulses or hits in a given location. The color is independent of the time at which video is applied to the tube.

The direction of color shift, halftone level at which color shift begins, rate of color shift and color saturation at equilibrium brightness may be optimized by electronic adjustments external to the tube itself. This straightforward associated circuitry is easy to operate and adjust.

The color tube may be fabricated with either the standard direct view storage tube or Multimode storage tube capabilities. In addition to the color-shift display, a monochromatic halftone mode of operation in one of several colors is provided. System applications are suggested.

## A DISPLAY SPECIFICATION

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## ABSTRACT

In the process of procuring an electroluminescent (EL) display system, it was necessary to develop (1) a definition of the display requirements and terminology consistent with the manufacturer's terms; (2) specify the product required in measurable parameters; and (3) establish the measurement techniques, instruments and procedures.

The basic nature of the electroluminescent illuminant, insofar as it is a non-thermal source, creates general distribution and color definition difficulties as well as brightness definitions. Also the factors of illumination color and quiescent color, in addition to their associated contrasts and susceptibility to ambient effects, created requirements for new definitions, terminology, and measurements.

Results of the study, development, and measurement effort have not been wholly satisfactory. Difficulties still exist in definitions of standards, instruments for measurements, and to some extent, understanding of nature of the EL lamp. What was achieved is a general specification for Electroluminescent Indicator Lamps, a model Material Specification for EL lamps and test data to determine effectiveness of these solutions. The specification covers design, construction, performance, test methods, test equipment and calibration for the EL lamp.

This specification and its problems are presented to the members of the Society for the consideration and evaluation in the hope that it will further solutions to the display measurement, specification and terminology.

## CONSTRUCTING DATA PICTURES

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Abstract

The advantages of using graphic displays for presenting data to human observers are well known and documented. The advantages appear to be due to the fact that measures can be sensed more directly when shown as geometrical properties in some physical model than when presented in the form of arbitrary symbols. If we represent a measure by its conventional symbol, "2" for example, it is in no visible sense half of four or one-third of six, but when it is represented by a length of line or by the position of a point it is. Conventional graphic displays are largely limited to the "length of line-position of point" approach. This has been partly a matter of habit, but mostly a matter of convenience and economy. Large amounts of data from many research disciplines, however, have forced us to explore for some more global graphic techniques, and developments in computer graphics have made a number of new approaches economically feasible. The present paper will suggest some new approaches to graphic displays in which data measures control a wide variety of geometrical properties in a data picture. The resultant displays may take on the appearance of some substance or process, and the subjective "data analysis" may be in the form of certain physical descriptions of the display such as descriptions of its softness, flexibility, jaggedness, bushiness, etc.

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SOME NOTES ON MEASURING PERFORMANCE OF  
PHOSPHORS USED IN CRT DISPLAYS



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ABSTRACT

The technique used for measuring brightness of a cathode ray tube display has considerable bearing on the results obtained. Line and raster type measurements are compared and it is shown that there are advantages to be obtained by measuring the brightness of an isolated line with a spot photometer. However, this instrument can only be relied upon if certain precautions are taken; these are discussed.

A display is usually required to achieve a specified writing brightness, which is a function of Cathode Ray Tube beam current, spot size, accelerating voltage, screen material, writing speed and refresh rate. When designing an efficient system the inter-relationships between these parameters are important and are considered with other constraints such as freedom from flicker.

The connection between each of these parameters and brightness often becomes obscured by comparing systems which may use different phosphors for the CRT screens, different guns and different combinations of operating conditions. The results outlined in this paper have been obtained from tubes with several phosphors deposited on each of their faces; in making screen comparisons this almost eliminates the effect of the gun.

The distribution of brightness in a spot is used to establish the effect of the relative sizes of the spot and the spot photometer aperture. The experimental results from measurements of many commonly used phosphors are then used to develop an empirical formula connecting the properties of the screen, refresh rate, beam current, writing speed, spot diameter and accelerating voltage. Measured values are given for thirteen screens operating over a wide range of conditions.

Finally, a brief investigation of flicker and its relationship to refresh rate for a few screen materials has produced some interesting results. In particular, it is shown that persistence is not a good criterion for the critical frequency.

## APPLICATION OF THERMOCHROMIC MATERIALS IN DISPLAY DEVICES

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Abstract

The feasibility of using thermochromic materials in display devices is currently under study. These materials exhibit color changes when heated and revert back to their original color when cooled. The observation of the color change depends on a change in reflection and not on the emission of light, as is the case in electroluminescent materials. Thus, displays utilizing thermochromic materials are visible under wide ranges of ambient illumination. Two prototype numeric display devices have been constructed in which pure ternary compounds,  $\text{Ag}_2\text{HgI}_4$  and  $\text{Cu}_2\text{HgI}_4$ , were used as the thermochromic display materials. These prototypes gave high contrast images and demonstrated the feasibility of devices of this kind. Various new thermochromic materials have been prepared. Some of the more important properties of thermochromic materials, such as their stability, reversibility, thermodynamic characteristics and contrast are presented. Experiments are described in which a laser beam was employed to "write" on a thermochromic material, and others in which the thermochromic material was substituted for the phosphor in a cathode ray tube.



EVALUATION OF PROBABILISTIC DISPLAYS

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Abstract

Many situations in which humans are required to act are probabilistic in nature. That is, the human is required to respond in a situation where he is presented with uncertain or fallible information. In such a situation, it may be useful to present information to the human using a display in which the essential probabilistic structure of the information is preserved and explicitly presented. This paper presents a study of four different probabilistic displays. The effectiveness of operators in estimating probabilities using these displays and in making decisions with such displays is evaluated and compared with the effectiveness of operators using a non-probabilistic (conventional) display. The results support the feasibility of probabilistic information presentation.

## HUMAN FACTORS IN AIRBORNE TELEVISION DISPLAYS

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## ABSTRACT

Recent advances in the capability of electro-optical imaging systems, particularly with respect to light sensitivity, have caused an increasing interest in television displays for military aerial operations. Each type of mission calls for its own particular design characteristics to optimize operator effectiveness. This paper discusses the variables involved in television viewing related to visual interpretation.

The principal variables which must be considered are: (1) the mission characteristics, (2) the imaging system, including contrast rendition, line coverage and signal-to-noise properties, (3) human visual capabilities, in terms of resolution and contrast perception and search time, and (4) viewing conditions such as kinescope size and shape and the ambient environment.

One of the most important factors influencing the selection of display characteristics for airborne use is the nature of the observation task which is involved. Performance capability related to the nature of the targets sought, altitude and velocity conditions is discussed, and data is presented from simulation research showing how visual in-

terpretation is influenced by the resolution and noise characteristics of the display system. Cockpit environmental factors such as the ambient illumination and space limitations are analyzed with respect to their influence on the display requirements. The presentation concludes with a summary of the operator-oriented system analytic approach necessary to the definition of display system performance specifications.

## 1. INTRODUCTION

To set the stage for the analysis which follows, we may consider that a military mission employing a television monitoring task is similar, in some respects, to the "mission" of flying from Los Angeles to Boston in one of the aircraft carrying closed circuit television as in-flight entertainment. For in-flight viewing, the camera is made operable just as the aircraft pulls away from the ramp. The first view is a forward look at the runway - "what the pilot sees" - so that takeoff may be observed out the window or at the display. After takeoff, the camera is dropped to provide a vertical view of the ground below. Monitors for viewing are placed between each pair of seats in

## EVALUATION OF NARROW BW T.V. DISPLAYS

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## ABSTRACT

The design of a narrow BW TV for transmission over acoustic channels is being investigated. Among the problems associated with such a system are the identification of the properties of various scan formats which maximize the amount of usable information which can be conveyed by the system, and the determination of the limits of the observer's ability to make the kinds of discriminations which might conceivably be required with the use of such a system. The approach being followed involves performance of certain visual tasks selected to develop and sample relevant perceptual criteria. Among these tasks are discriminations of simple shape and line orientation, recognition of hidden objects, and determination of thresholds for angularity and curvature. Also under study is the possible advantage afforded by stereoscopic viewing as opposed to ordinary two-dimensional presentation. Special attention is being given to pseudo-random dot scans, and dot-line interlaces, since conventional line scans at the reduced bandwidths under study result in frame rates which are unsuitable for practical use. Basic results and technical considerations will be discussed.

THE DESIGN AND DEVELOPMENT OF A COMPUTER DRIVEN  
ELECTROLUMINESCENT VERTICAL SCALE INDICATOR



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ABSTRACT

The design and development of a digital computer driven electroluminescent (EL) vertical scale indicator under contract NAS 7-420 with the National Aeronautics and Space Administration\* involved the application of advanced techniques to the fabrication of a spacecraft instrument. The presentation describes the design, the developmental problems, and the solutions chosen for the fabrication of two types of solid-state instruments. Emphasis was placed on size, weight, power, reliability, and display readability consistent with conditions encountered in a spacecraft environment. Detailed data are presented describing the digital microcircuit, EL lamp controls, and EL lamp selection and performance results. The EL lamp brightness regulated display concept utilized is described in detail.

The fabrication of the instrument is continuing and existing units will be evaluated by NASA in a simulation environment. The flexibility provided by this design will allow display color combination, observer evaluation of the functional presentation method. The process of new presentation methods is necessary to provide instruments that can support man's expanding effort in the exploration of space.

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\* Ames Research Center

## TWO-SLIT SPOT ANALYZER



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### Abstract

The Two-Slit Analyzer is an instrument designed to simplify the task of making measurements of Cathode Ray Tube spot size. The working definition of spot size is the "width at the half-amplitude" of the energy distribution in the spot.

Distance calibration is built into the Two-Slit Analyzer. It is useful for making all of the many types of resolution measurements used in Cathode Ray Tube displays. Two-line raster, single-line raster, shrinking raster, bar chart resolution, spatial frequency response, linearity, phosphor noise, rise and decay time measurements can be made in addition to "width at half-amplitude".

The Two-Slit Analyzer is relatively simple to use, accurate and reliable. Operator decisions and eye fatigue are eliminated in measuring resolution.

A standard method for CRT spot measurements is suggested which will be useful in computer, radar, television and other types of information displays in defining performance of CRT's, deflection yokes, focusing coils, astigmatic correctors and associated devices which effect performance at the display interface.

## A MULTICOLOR LASER DIGITAL DATA DISPLAY SYSTEM



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### ABSTRACT

A large-screen, digital data display system which is presently being developed will be discussed. This real-time, projection display system is particularly suited for on-line operation with a digital computer. Coherent light from red, blue and green lasers is modulated and deflected to produce a 512- by 512-point, seven-color display. System specifications call for a 10-foot-lambert brightness display on a 5-foot by 5-foot rear projection screen. The design is such that the resolution can readily be increased to 1024 by 1024 points.

This laser display system differs from the previously described television type, raster scan laser displays in that all 262,144 points of a computer-generated image are stored magnetically and reproduced 60 times a second to generate a flicker-free display image. The means of scanning is such as to insure nearly perfect linearity and color registration.

The display's update rate is limited only by computer information transfer rates and can exceed one million bits per second.

The optical and electronic design of the display will be described with particular attention being given to laser selection, light modulation and deflection techniques and image storage.

A 210 kc/sec PHONEVISION SYSTEM



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ABSTRACT

The principal psychophysical requirements of the human eye are satisfied by a television frame frequency of about 1 or 2 cps. To avoid flicker with low frame rates, a pseudo-random dot scan is employed in conjunction with a medium-persistence phosphor. A 210 kc/sec phonevision system is described that has 100,000-element pictures and a frame rate of 3.75 cps.

## HIGH DENSITY TAPE RECORDING OF REDUCED-BANDWIDTH TV SIGNALS\*

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### I. INTRODUCTION

The frequency response of a signal recorded on one track is limited by different factors, such as: Practical tape velocity, final width of the head gap, graininess of the tape, etc. In order to be able to increase the frequency response of the recording, without going into the inefficient and expensive high speed recording, we take advantage of the width of the tape. There are two methods to do that. The one currently widely used for television recording is recording with rotating heads sweeping transversely across the tape, the longitudinal tape motion being just fast enough to space properly the transverse tracks. The disadvantage of this system besides being quite expensive is that its mechanical construction is extremely complex, sensitive and requires extensive maintenance. The other method, which is used in our system, is multi-track recording.

The most obvious thing would be to use time division multiplexing, i. e. divide the high frequency signal through sampling into a number of low frequency channels and record each onto a separate track, and then reassemble them into the original signal after playback. This would allow us to record a signal of approximately 360 kHz on a 1/4" tape running at 15"/sec since eight tracks each having about 45 kHz bandwidth can be recorded on 1/4" tape. However, this is not as easy as it seems due to skew and flutter of the tape.

Skew is defined as the variable time displacement encountered between different tracks at playback. Therefore, when skew is present the samples would not be read out at the proper time or even sequence. It is impossible then to reassemble the signal.

Flutter is defined as the velocity variation which is uniform across the tape. While flutter is bothersome even in recording on one track, it is impossible to generate the sample signals in order to sample the different tracks.

To overcome those difficulties an electronic skew and flutter compensation system was developed.

### 2. GENERAL DESCRIPTION OF THE SYSTEM DEVELOPED

The signals to be recorded are obtained from the pseudo-random scanned TV System. Since the recording system has to be reasonably economical, a tape drive using 1/4" tape at a velocity of 15 inch/sec. was thought to be satisfactory.

The flutter and skew compensation system that is used has two reference signals recorded on the two outer tracks. All other tracks can be used for recording of multiplexed data. Sound is also recorded on the reference signal tracks. The maximum number of tracks that are normally recorded on a 1/4" tape is eight. All those tracks have to be recorded (played-back) using heads mounted in one

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## PULFRICH SPACE FORM

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## ABSTRACT

A little-known stereo effect, the Pulfrich stereophenomenon, is capable of producing stereo depth from single displays in a dynamic situation. A virtual depth excursion is generated by a stimulus point (target) moving horizontally, when the observer receives unequal binocular retinal illuminances (obtained, for example, by viewing with a neutral density filter before one eye).

The effect is attributed to the existence of a significant time delay between retinal stimulation and receptor response, and the resulting differential delay that exists when viewing ala Pulfrich. This differential delay in a dynamic display produces a retinal image disparity resulting in stereo depth. The subjective space form so produced is the Pulfrich space form PSF.

The Pulfrich effect can be most simply studied with mechanical arrangements; for example, using an oscillating pendulum bob as target. Another system making use of an oscilloscope allows virtually any target motion to be conveniently produced, and permits the use of complex target shapes. A further experimental refinement is to use a stereo oscilloscope. This device offers two advantages: (1) differential intensities can be used on the two CRTs to produce a range of differential retinal illuminances for the two eyes; (2) a real pattern disparity can be introduced to test its interaction with the subjective Pulfrich effect. Experiments with such instruments have shown that the Pulfrich effect is capable of completely negating the effect of a real pattern disparity of the opposite type.

General functional expressions are given for determining PSF from the equations of motion of the target. Also, a graphical method is presented for use when equations are not available. It is shown that when target motion is sinusoidal, the PSF is elliptical. The PSFs corresponding to several target motions are given.

Indications are that applications may exist for the Pulfrich effect in some areas of 3-D data display.

EYE MOVEMENT TECHNIQUE  
TO MEASURE VISUAL SEARCH BEHAVIOR



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Abstract

One of the missions of the Display Techniques Branch at Rome Air Development Center is to identify variables which influence visual search behavior, investigate their interactions and specify standards which should be used in designing and evaluating Large Scale Display Systems. In the Information Techniques Section of the Display Techniques Branch, this research has been two-pronged. First, "in-house" and contractual efforts primarily in the area of psychophysical studies (color specifications, coding, TV resolution) and secondly, display criterion development. This latter has as its purpose the development of a metric to evaluate the information transfer potentiality of Large Scale Display designs.

In the area of Visual Search, the Information Techniques Section has recently turned its attention to the development of an eye movement device which would aid in evaluating the influences of various display parameters and be an additional diagnostic tool in the criterion development field. This paper will present the approach used in developing this device and a more detailed explanation of possible uses of the apparatus.

A SOLID STATE MATRIX DISPLAY EMPLOYING  
GALLIUM PHOSPHIDE DIODES

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ABSTRACT

This paper describes a solid state diode matrix display employing Gallium Phosphide light sources, which have been devised to investigate the possibility of use as a solid state display and a data recording device. The matrix is composed of 4 (rows) x 5 (columns) diodes which emit light of about 7000 Å in wave length with a quantum efficiency of about 0.5% when forward biased at 4 to 8 volts. By making use of the above mentioned characteristics of light emissive properties, the diode matrix was scanned by two separate scan generators for row and column lines respectively.

Characters 0 to 9 were successfully displayed on this device by a row pulse and a signal from an "AND" gate having input signals from column and character generator signals. According to the experiments with this device, the scanning speed per character is 40 μsec and the light intensity of a diode is 30 foot-lamberts at a current of 80 ma. As for the characteristics of light emission from a GaP diode, it was shown that its color changes continuously from red to green with increasing current as well as with the doping conditions of donors and acceptors. Green emission rather than red would be more fitted for use in a solid state matrix display for photographic recording since it matches the sensitivity of ASA 100 film for an exposure time of  $5 \times 10^{-6}$  sec.

## 1. INTRODUCTION

In response to the recent development of computers, the need for a matrix addressed display has been enhanced as means of man-machine communication. There are a few proposals (1) (2) about it, however, they are at present far from ideal. It is one of our aims to check the possibility of the application of the light emitting Gallium-Phosphide diode as a display device. In this paper, we will discuss experiments with a 4 x 5 diode matrix.

A diode matrix has been scanned by successive impulse voltages such that the characters 0 to 9 could be represented at the speed of 40 μsec/word.

From the point of view of light intensity and human vision, such a matrix as 150 x 150 diodes could be used for a display. Data recording experiments show that the green light from Gallium Phosphide blackens ASA No. 100 film approximately 30% in an exposure time of  $5 \times 10^{-6}$  sec.

Additionally, the light emissive characteristic of a diode doped with Ga<sub>2</sub>O<sub>3</sub> and Zn will be reviewed as well as a discussion of possible introduction of memory functions into a diode.

## 2. PREPARATION AND PROPERTIES OF A LIGHT EMITTING DIODE

Two kinds of diodes have been used in the experiments, one of which is a Sn-alloyed single crystal doped with Zn and Ga<sub>2</sub>O<sub>3</sub>, and the

other a p-n junction of GaP doped with Te and Zn. As is well-known, the light emission of GaP is due to the pair recombinations of electrons captured by donors with holes captured by acceptors.

When an electric field is applied, the single crystal doped by Zn and O emits light with a center wave length of 7000 Å, while that doped by Zn and Te or Zn and S has a light emission with a center wave length of 5600 Å.

### 2.1 GaP Doped with Zn and Ga<sub>2</sub>O<sub>3</sub>

By inserting the compounds of Ga, GaP, Zn and Ga<sub>2</sub>O<sub>3</sub> into a quartz-tube and heating and cooling gradually, we can obtain many crystals as small as  $2 \times 2 \times 0.3 \text{ mm}^3$ . As each of them is p-typed, a p-n junction is formed by alloying Sn on it. Figure 1 shows the relation between the doping quantity of Ga<sub>2</sub>O<sub>3</sub> and the intensity of emitted light when a current of 50 mA flows through a diode in which more than 30 mg of Ga<sub>2</sub>O<sub>3</sub> is doped to produce a sufficient amount of light emission.

The voltage-current characteristics of a diode are represented in Figure 2, which show that the reverse bias breakdown voltage is more than 8V and a current of above 100 mA flows for a forward bias of 8V. These characteristics enable its use for scanning of a diode matrix.

The relations of light intensity with a forward biased current are shown in Figure 3. It is typical that the intensity of light goes up exponentially with increasing current, which suggests the possibility of use as an optical memory.

## A PROGRAMABLE DISPLAY SYNTHESIZING SYSTEM

FOR MAN-MACHINE COMMUNICATIONS RESEARCH

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## ABSTRACT

Much of the experimental development required in the area of flight control-display interface design can be accomplished in the time-proven research simulator. However, the methods utilized to implement simulator display panels have been encumbered by the long time lags and high costs of instrument development and by the inflexibility and clutter of single-purpose instrument arrays. This paper describes a new concept for research simulator display, the purpose of which is to provide for a more effective, less costly, and less time-consuming means of creating dynamic instrument replicas for simulator evaluation. This concept employs the synthesis of desired instrumentation at the control-display interface of the man-machine loop utilizing a programable electronic display system.

The synthetic display concept described is based on an electronic animation technique which allows the cockpit display designer to proceed directly from static instrument mockups to dynamic displays which are simulated at the display interface by high-resolution closed-circuit monochrome TV. The electronic animation technique utilizes the principle that most desired flight displays are composed of static patterns and dynamic patterns which can be separated for photographic storage and, under the control of programmed instructions, machine dynamics, and manned inputs, can be electronically recombined for composite, dynamic display.

This paper includes a description of the display system configuration with regard to major components required to achieve electronic animation. Major subsystems described include a stored program control unit and a digitally controlled vidicon film scanner, flying spot film scanner, and scan converter. Programming techniques and system operational modes are discussed from the viewpoint of relating how dynamic and static display patterns are called up from random access film storage, how individual dynamic patterns are electronically modified, written into transient storage, and updated to convey motion, and how dynamic and static portions of the display are combined to form animated composites.

Examples of synthesized flight displays are exhibited. System performance is discussed and compared with that of conventional computer-CRT stylized displays. The advantages of electronic animation with regard to format change, program complexity, regeneration rates, and image characteristics for certain classes of displays are presented.

## MAGNETO-OPTIC DISPLAY

A class of magneto-optic devices has attracted the interest of the information recording, processing, and display community in the past few years. These devices can perform many of the functions associated with memory arrays; in addition, the state of an element in the array can be sensed optically. These properties, combined with the ability to fabricate arrays with more than  $10^6$  elements and drive them at computer rates with solid state drivers in a matrix format, make them attractive. Initial use will be in display. They will find use as interfaces between electronic and optical channels and ultimately as man-machine interfaces.

This paper presents the physics of the device, the present display characteristics, and a look at the future. The current state-of-the-art in operational magneto-optic displays, recited herein, has been sponsored by the U. S. Army Electronics Command under DA-28-043-AMC-01442(E).

## 1. Physics of Magneto-optic Display Device

## 1.1 General

The magneto-optic phenomena, subject in this paper, has evolved from the Bitter technique of studying domain structures in thin magnetic films. Specifically, a colloidal suspension of ferromagnetic particles (Bitter's solution) is placed on the surface of the magnetic film. The fringing field at the surface of the film, associated with the domain structure within, attracts the ferromagnetic particles. A glomerate of these particles is formed on the surface of the film along the domain walls. If the domain structure is sufficiently regular, the glomeration forms a regular line array or grating. This grating is capable of diffracting

light.

When the magnetization vector is rotated in the plane of the film, the domain structure also rotates. A new optical grating will be formed at the new location of the domain walls. The old grating is thermally dissipated by the Brownian nature of the Bitter solution. The film is magnetized in some preferred direction by means of a coincident current matrix, wire loop, or magnetic recording head. For coincident current matrix writing and erasing, the grating is usually rotated through  $90^\circ$ .

## 1.2 Magnetic Film

The films used in this work are electroplated nickel-iron. They are negative magnetostrictive isotropic tensile stress films of 10,000 to 40,000 Å thickness and are usually electroplated on a gold layer on a glass substrate. The film is switched by using creep rotation of the magnetic anisotropy. This results in angular rotation of the domain structure in and at the surface of the film.

## 1.3 Colloidal Suspension

The principal colloidal suspension used in these devices is an aqueous suspension of magnetite,  $\text{Fe}_3\text{O}_4$ . Particle size is about 100 Å. Nonaqueous suspensions have also been evaluated. The colloidal suspension of ferromagnetic particles is sealed between the top surface of the nickel-iron film and a cover glass.

Aqueous suspensions are superior in both brightness and contrast to the nonaqueous suspensions examined. Some initial difficulty with useful device life was experienced. Modifications to the seal and film have increased device lifetime to more than

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